DELFT UNIVERSITY OF TECHNOLOGY		Faculty Aerospace Engineering
Course : ae4-870B – Re-entry Systems		**Course year: 4**
Date : xxx	**Time: xxx**	**Location: xxx**

MARK EACH PAGE WITH THE CODE ae4-870

Remark:
Write down your name and all initials on each page. Fill in all entries of the rubber stamp in the top right hand corner. The use of a lead-pencil is only allowed on scratch paper, which may not be submitted as part of the examination work.

All questions have to be answered. The questions should be answered carefully in well-readable handwriting and illustrated with clear figures, if required.

Sample Question

A re-entry vehicle returns in the atmosphere using a repeating skipping trajectory, entering the atmosphere twice. At first contact with the atmosphere, the entry angle $\gamma_E = -15°$ and the entry velocity $V_E = 8$ km/s. The lift-to-drag ratio of the vehicle is: L/D = 1 (constant).

a) Set up the general equations of motion for a re-entry flight in the directions parallel with and perpendicular to the velocity vector. For the skipping trajectory, derive from these equations an expression for the relationship between velocity and flight path angle and another expression for the relationship between flight path angle and air density, the latter under the assumption of an exponential atmosphere. Indicate which simplifying assumption(s) is/are made in this derivation.

b) Next, draw a clear sketch of the variation of the velocity as a function of the flight path angle from the moment of first contact with the atmosphere until the second exit. In order to make this sketch, both parameters have to be computed in the following characteristic points of the trajectory:

- lowest point of the first skipping trajectory;
- exit of the atmosphere at the end of the first skipping trajectory;
- highest point of the (ballistic) flight after the first skipping trajectory;
- atmospheric entry point of the second skipping trajectory;
- lowest point of the second skipping trajectory;
- exit of the atmosphere at the end of the second skipping trajectory.

If you have problems to compute these quantities, then at least try to make a qualitative sketch and motivate your ideas about the variation of the velocity as a function of the flight path angle.

c) Derive an expression for the air density in the lowest point of the skipping trajectory as a function of the entry conditions. Next, compute the altitude of the lowest point of both parts of the dual skipping trajectory. For this purpose it is given that the "lift parameter" of the vehicle ($W/(S*C_L)$) equals 0.2 N/cm^2 , while the density scale height H = 7 km and the constant of gravitational acceleration g_0 = 9.81 m/s^2. The expression for the air density as function of height in an exponential atmosphere may be applied without derivation (density at sea level: $\rho_0 = 1.225$ kg/m^3).